

THE VEGETATION OF THE BOORABBIN AND LAKE JOHNSTON AREAS, WESTERN AUSTRALIA

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(Plates XVIII–XXII)

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Synopsis

The purpose of this paper is to present two vegetation maps from Western Australia on the scale of 1 : 250,000. The two are contiguous and conform to the standard series of topographic maps on this scale. The locality is east of the Western Australian wheat-belt in undeveloped country between Southern Cross and Coolgardie, Lake King and Norseman. Mapping was done from aerial photography. Methods of the survey and the classification and terminology adopted are outlined. A mapping notation developed for the purpose is presented for the first time. Factors of the environment are described and the mapped communities dealt with in detail as to physiognomy and composition. Three shrubland and five woodland types are recognized which combine variously into five vegetation systems, in which the plant communities and their related soils occur in catenary sequences.

GENERAL DESCRIPTION

This paper relates to the two contiguous map sheets of the 1:250,000 Series, Boorabbin and Lake Johnston which cover country between 31° and 33° S. latitude, 120° and 121°30' E. longitude. The area concerned lies in general terms to the south-west of Coolgardie, which is only ten miles off the Boorabbin sheet at its north-west corner. The area then extends 90 miles westwards from Coolgardie towards Southern Cross, and 140 miles southwards towards Esperance and the coast, excluding Norseman which, like Coolgardie, lies just off the margin of the area. Road, rail, water and telegraph communications between the west coast and the eastern goldfields traverse the north of the Boorabbin sheet. Similar lines of communication from Coolgardie to Esperance cross the north-east corner of the Boorabbin sheet and continue southwards just east of both map margins for their entire length. A main road crosses the southern part of the Lake Johnston sheet from Daniel to Lake King, a road which is readily traversable and in good condition. A rather less frequented graded track crosses the northern part of the same sheet from Norseman to Hyden. Otherwise, as the country is uninhabited, there are virtually no roads and only a few bush tracks.

The first exploration of this area took place from the south under J. S. Roe in 1849, when Peak Charles was named after the Governor, Charles Fitzgerald. In 1863 H. M. Lefroy traversed the northern portion. The Johnston Lakes were named by a prospector, Frank Hann, in 1901 after the Surveyor-General, H. F. Johnston. Following the discovery of gold at Coolgardie in 1892 communications with the coast along the present line of the railway and water pipeline were established, and in 1893 Holland pioneered a route from Broome Hill near Katanning to Coolgardie. This route, "Holland's Track", crossed the Boorabbin sheet diagonally from S.W. to N.E. The northern part of it from Pigeon Holes to Coolgardie has become a graded road, but the southern portion has been lost.

We have little precise record of any botanical collecting in the area. Diels and Pritzel travelled through by train in 1901 and recorded some observations. In recent years collecting has been done by such botanists as C. A. Gardner and R. D. Royce and the plant cover is reasonably well known in a general way. The area was included in the Coolgardie District of the Eremaean Botanical Province by Diels (1906), which was maintained by Gardner and Bennetts (1956). Burbidge (1960), however, has placed the Coolgardie District in an interzone lying between the Eremaean and Southwestern Provinces. Gardner's (1942) map of the vegetation of Western Australia shows the whole area as Sclerophyllous Woodland but this clearly is intended as a broad generalization, having regard to the scale of the map (about 1:8,000,000). Other vegetation maps which include Western Australia such as in Williams (1955) are equally generalized, due to their scale and the absence of detailed field work.

The Boorabbin area was geologically mapped by J. Sofoulis and W. Bock in 1960, and a geological map at 1:250,000 with explanatory memoir published in 1963. The Lake Johnston area has not been geologically examined in detail, nor mapped. In May 1964 the writer travelled through the Boorabbin area with J. Sofoulis, who explained the correlations between vegetation and underlying soil and geology which had been observed in the course of geological mapping. Botanical specimens were collected and numerous important plants, especially the trees, identified. In October 1964 the writer, assisted by F. Lullfitz, traversed the Lake Johnston area from Lake King to Norseman with diversions to Hatter's Hill, Lake Hope and Peak Charles, and returned from Norseman on the Hyden Road as far as Forrestania with a diversion to the Bremer Range, then going north to Southern Cross and east along the main road to do spring collecting in the Boorabbin scrub heath. Four hundred botanical specimens were collected and subsequently identified, partly by Mr. C. A. Gardner and partly by the Curator and staff at the Western Australian Herbarium, whose assistance is gratefully acknowledged. The object of the field work, however, was not to obtain comprehensive collections to establish the total floristic composition of each plant community, desirable though that would be. This would have required very much more time in the field, and in any case there would have been no facilities for identifying a much greater number of specimens. The objective has been ecological, to determine the plant communities occurring in the area, to map them, and to furnish the essential details of their composition and physiognomy.

Following the field reconnaissance, the mapping was done from controlled 1-mile to 1-inch aerial photo-mosaics furnished by the Department of Lands and Surveys. Much time was saved by the kindly loan by the Geological Survey of the original photographs used by the geological field party in 1960 for the Boorabbin area, since after consultation with the party leader, Mr. J. Sofoulis, his interpretations could be readily adapted for vegetation mapping. In this part of the country rock exposures are few and the underlying strata are buried beneath a thick overburden. The geological map is thus to a large extent essentially a soil map and was prepared by interpreting vegetation patterns on the aerial photographs as soil. In the Boorabbin sheet there will be found to be a general similarity between the boundaries shown on the vegetation and geological maps. The main differences consist in the subdivision for vegetation purposes of the "Residual Sandplain" areas into scrub heath and broombrush thicket, and the inclusion of all the areas of basic rocks and included granites in the northeastern sector within a single association of sclerophyll woodlands.

The Lake Johnston sheet was mapped purely from original photo-interpretation by the writer on the scale 1:62,500. The outlines were reduced photographically by the Department of Lands and Surveys and prepared for publication at King's Park.

FACTORS OF THE ENVIRONMENT

Physiography

The country included in these map sheets is a part of the interior plateau of Western Australia and lies between 700 and 1500 feet above sea level. With the exception of the group of the abrupt Fitzgerald Peaks in the south-east, of which the largest, Peak Charles, reaches a height of 2160 feet, relief is subdued. Ridges are broad and flat and alternate gently with valleys which are also broad and flat, the difference in level from ridge to flat being rarely more than 300 feet with slopes falling about 25 feet per mile.

The area is divided into five Vegetation Systems (see page 259), distinguished as the Boorabbin, Coolgardie, Cave Hill, Bremer Range and Lake Hope Systems (Fig. 1). Each of these has a characteristic physiography, geological structure and soil association as well as its characteristic

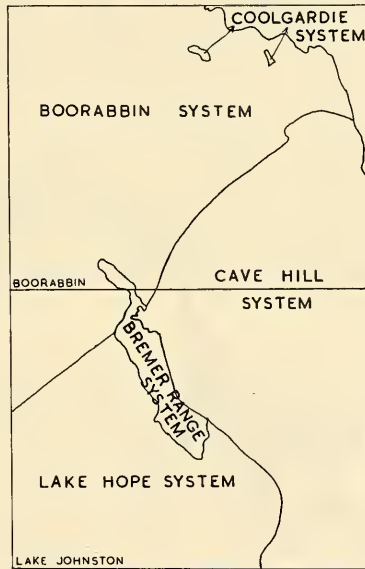


Fig. 1 VEGETATION SYSTEMS

vegetation pattern. In the Boorabbin System the country consists mainly of a dissected upland developed on granite with widely spreading sandy plateau surfaces up to 1500 feet in altitude and valleys down to 1200 feet, draining mainly to the north. In midslope there may at times be a small lateritic scarp or "breakaway" and also bare outcrops of granite which are moderately common. They have a low outline and rarely project much above the surrounding country. The valleys are relatively narrow and contain chains of small salt lakes. The Cave Hill System is also a granite upland, but much more strongly dissected, so that little of the old sandy plateau remains; it is hilly on a smaller scale and granite outcrops are very abundant, Except for the Fitzgerald Peaks, however, they rarely form prominent features. Valleys are broader and there are some larger salt lakes. The Lake Hope System is again a granitic upland, but developed under a higher

rainfall to a still more advanced stage of dissection. Traces of the sands and lateritic gravels of the "old plateau" surface on high ground are rare and granite outcrops quite rare. Solonchic soils carrying mallee vegetation have developed over the rising ground, valleys are very broad and flat and contain large salt lakes. Relief is from 800 to 1100 feet above sea level.

The Coolgardie and Bremer Range Systems are developed upon greenstones, mainly basic rocks such as ancient basaltic lavas and metasediments, with included granites. These outcrops tend to occur in belts trending N.N.W.-S.S.E. and form small hilly ranges with rounded rocky hills and broad alluvial areas at their foot. Relative elevation in the Bremer Range is only 300 feet.

The physiography of the whole area of these two maps is dominated by a main watershed (see Fig. 2) running more or less diagonally across

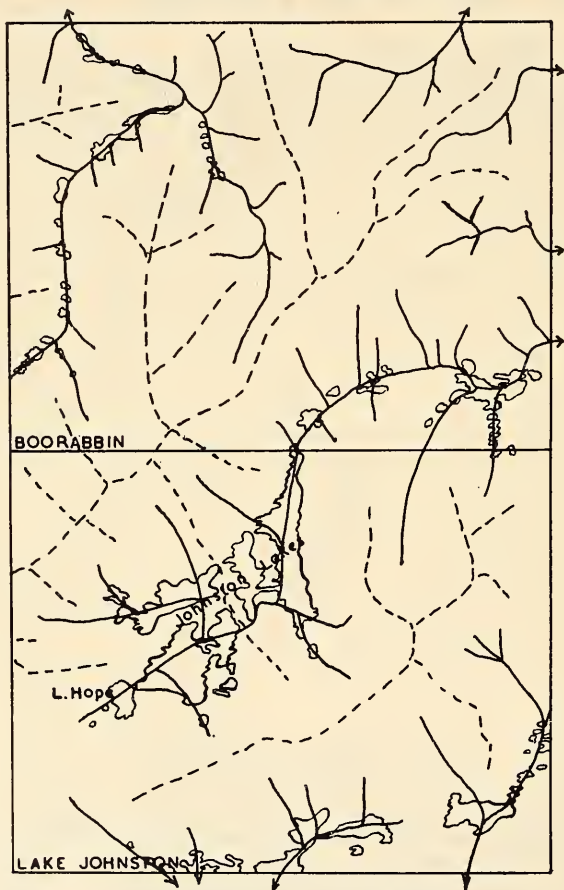


Fig.2 DRAINAGE PATTERNS

the Boorabbin sheet from S.W. to N.E. and at a general height of 1300-1500 feet. A second parallel ridge 1000 to 1200 feet high occurs 40-50 miles to the S.E., and it is between these two ridges that the extensive and complicated system of the Johnston Lakes has developed. In the whole region there are no permanent streams, and indeed there are hardly any well-defined channels for flood run-off. None the less the country shows a definite pattern of ridge and valley which must have been excavated by

a coherent river system, presumably in earlier times under a higher rainfall régime. Figure-2 is an attempt to sketch the ancient drainage system by inserting hypothetical streams in the valley bottoms where today there are only chains of salt lakes with little or no actual flow from one to the other. Crests of the interfluvies are shown dotted. North of the main ridge the valleys trend northwards and it is thought that this drainage originally passed westward to the Swan River. On the east side of the Boorabbin sheet drainage is eastwards towards Lake Lefroy. Elsewhere, south of the main ridge, the country slopes generally towards the sea, and it is reasonable to suppose an original connection with those river channels which still actually exist on the south coast such as the Oldfield and Lort Rivers.

The Bremer Range forms a ridge following the line of strike of the basic rocks, which is thus at right angles to the main direction of the ridge and valley system developed upon the granite. However, the ridge is a low one and appears to have been breached by the ancient river system.

In the present epoch the process must be one of filling up the ancient valleys by silt and evaporites derived from nearby hills. Some parts of the valleys would tend to receive more deposit than others, raising the level relatively more and leading to ponding elsewhere. Evaporation then leads to accumulations of salts, vegetation is killed at a certain critical level and playa lakes come into being. These may be extended later by wind action and by further salt accumulation.

If it is postulated that in the past a period of higher rainfall is necessary to account for the development of the present topography, or more than one such period, then one or more periods of greater aridity are equally reasonable and indeed are evidenced elsewhere on the continent. During an arid phase aggradation of valleys might well occur more rapidly than at present, and have initiated the formation of the salt lakes. It might be possible by careful study to discover the effects of such climatic fluctuations upon landform.

*Climate**

As most of this country is unsettled, rainfall records are available only for a few places near the northern boundary. Maps based on these records and others reasonably close to the area show that the 11 inch isohyet runs roughly northwest-southeast through the northern part of Lake Johnston, dividing the area approximately into halves. The lowest rainfall is just below 10 inches in the far northeast, and the highest is 13 inches, on the eastern part of the southern border. In about 90% of the area annual rainfall is between 10 and 12 inches, there being only a comparatively small area near the southern border with 12 to 13 inches, and a still smaller area in the north with less than 10 inches.

In the southern part the wettest six monthly period is the same as in most of the agricultural area, i.e. May to October. However, further north, and in about four-fifths of the area, the wettest period is March-August. Almost throughout the area, the average rainfall is higher in March than in April, and in the north, where the late autumn and winter rains are comparatively light, this results in the March-August period being wetter than May-October.

In the far south, monthly averages give the impression of almost uniform rainfall, as at Salmon Gums, for instance, they exceed one inch in the period March to October inclusive, and are between three-quarters of an inch

* The data which follow were contributed by the Commonwealth Bureau of Meteorology by courtesy of the Regional Director, Perth.

and one inch in each of the remaining four months. However, the comparatively high averages of these four months are due not to consistent totals of about three-quarters of an inch to one inch, but to many dry months, a smaller number of moderately wet months and a few very wet ones.

Table 1 shows rainfall data for Coolgardie, Widgiemooltha and Salmon Gums.

TABLE 1
Rainfall data
(Points)

	No. of Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
<i>Coolgardie</i>														
Average	63	65	98	96	89	109	112	93	98	54	68	60	65	1,007
Median	72	26	60	52	52	94	105	87	65	44	36	31	41	
Highest month	72	643	933	527	415	454	469	297	356	364	309	306	350	
Lowest month	72	0	0	0	0	1	7	0	3	0	0	0	0	
Highest day	72	462	533	230	203	167	193	112	186	92	259	154	190	
<i>Widgiemooltha</i>														
Average	65	74	98	110	104	116	116	93	98	67	78	73	66	1,093
Median	65	38	40	50	60	90	105	74	77	50	53	54	30	
Highest month	65	543	1,054	592	569	591	463	326	330	384	393	342	407	
Lowest month	65	0	0	0	0	0	0	3	0	0	0	0	0	
Highest day	65	345	1,050	220	273	172	220	150	122	147	198	203	208	
<i>Salmon Gums</i>														
Average	43	83	95	110	104	131	155	146	131	125	108	77	76	1,341
Median	43	42	41	58	87	117	138	140	124	100	80	60	49	
Highest month	43	553	410	694	416	435	410	333	381	374	326	280	288	
Lowest month	43	0	0	0	0	4	45	25	21	12	0	0	3	
Highest day	40	355	323	415	178	170	132	95	153	268	120	138	131	

Evaporation

Evaporation ranges from 55 inches per year at the southwestern corner to 92 inches in the far northeast. The rate of evaporation is highest in January, when totals for the month at these places are 10 inches and 15 inches respectively. They are lowest in July, when the range is from 1.7 to 2.5 inches.

Growing Season

The length of the growing season may be estimated from curves of "effective" rainfall (based on evaporation) and average rainfall. These values are applicable to introduced species drawing their moisture supply from a comparatively shallow depth, and are not necessarily applicable to native vegetation. However, they enable growing conditions in this area to be compared with those in the agricultural area and are included for that reason.

The growing season is longest on the southern border of the region, where it reaches four months, and is about the same length as in much of the wheat belt along a line from Kellerberrin to Northampton. In about one-third of the area the length of the season is between four and three months, this being equivalent to the season in the marginal wheat belt country. In a little more than one-third of the area the length is between three and two months, while in the northeastern quadrant it is less than two months.

Although the length of the season in the southern part of this area is about the same as in much of the wheat belt, there is a smaller surplus of rainfall here during the growing season. On the other hand, a small surplus of rainfall above the average for the months preceding or following the normal growing season, would cause a greater increase in the length of the season in this region than in the main wheat belt.

Temperature

In summer, temperature increases northward, the range in February, the hottest month, being from a mean maximum of 85° in the southeastern corner to 94° in the northwest corner. In winter, mean minimum temperature is lowest in the southern half of the area, but increases towards the southern border, and also over the northern half of the area. The range of mean minimum is from a little below 39° in the coldest part to a little over 41° in the far northeast.

It has been found that light frosts occur with screen temperatures of 36° . In an area with a mean minimum of 39° it is obvious that frosts will occur frequently, and some will be severe. Table 2 shows temperature data for Southern Cross, Coolgardie and Salmon Gums, the climatological stations closest to the area. The frequency of temperatures below 36° has been included in this table as an indication of frost frequency.

Wind

One station in this area (Boorabbin), recorded wind for $2\frac{1}{2}$ years, and the 9 a.m. records for this centre show that from November to April winds are mainly easterlies, E./S.E. being a little more frequent than E./N.E. in January and February, and the reverse in the other four months. There are very few winds with a westerly component during the December–March period, but they become more frequent in April, and from May to August westerlies predominate, though not to the same extent that the easterlies did earlier in the year. Winds in excess of 30 knots were recorded only three times, from directions of W.S.W., W. and W.N.W. Most of the winds in excess of 20 knots were from the northwest quadrant.

At Norseman, winds from the northeast quadrant predominate from January to May, with W./N.W. winds becoming more frequent in May, and predominating from June to September. In October winds become more variable and although there are still a fair number from W./W.N.W. there are more from S./S.S.E. and from N.E./N.N.E. In the November and December southerlies prevail, but are not much more frequent than north-easterlies.

At Coolgardie the prevailing direction at 9 a.m. is N.E./N. from October to April, and S.W./W. from May to September. At 3 p.m. N.E./N. winds prevail from November to March, N./N.W. in April, and S.W./W. from May to October.

Table 3 shows the diurnal variation of prevailing wind at Southern Cross. In this table winds from the direction preceding the stroke are more frequent than from the direction following it.

Human Influences

Owing to the low rainfall of the Boorabbin and Lake Johnston areas there has been virtually no agricultural settlement, the only developed section being confined to approximately 900 acres in the extreme south-east centred upon Kumarl, which lies a few miles east of the sheet boundary. There are no pastoral leases at the present time, though two areas of 56,400 and

TABLE 2
Temperature Data

	Number of Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
<i>Southern Cross</i>														
Mean maximum	43	94.3	93.0	87.0	78.9	69.5	63.0	61.7	64.7	72.0	77.7	86.5	92.3	78.4
Mean minimum	43	62.2	62.2	58.4	51.7	45.1	41.5	39.1	40.3	43.1	47.9	55.0	59.9	50.5
Highest	64	115.0	117.0	112.0	103.2	92.2	81.5	80.0	85.9	94.6	102.8	110.2	114.6	117.0
Lowest	64	42.0	42.0	38.2	30.0	26.0	24.3	23.0	25.0	26.0	30.6	35.6	40.8	23.0
Average number $\geq 100^{\circ}$	24	12	7	3	0	0	0	0	0	0	0	2	5	27
" $\geq 90^{\circ}$	24	24	18	13	3	0	0	0	0	0	3	10	19	88
" $\geq 36^{\circ}$	10	0	0	0	0.4	3.0	7.9	10.8	8.6	4.4	1.0	0	0	36.1
<i>Coolgardie</i>														
Mean maximum	30	91.9	91.4	84.9	76.9	68.9	62.5	61.2	64.6	72.1	77.4	84.9	89.9	77.2
Mean minimum	30	62.6	62.6	59.6	53.2	47.4	43.4	41.4	42.4	46.3	50.5	56.3	60.4	52.2
Highest	65	115.0	114.3	110.0	103.0	91.8	79.3	81.0	85.5	94.0	103.0	109.0	111.0	115.0
Lowest	65	46.0	46.6	41.0	36.0	33.2	30.2	29.0	30.8	31.0	34.0	37.4	43.0	29.0
Average number $\geq 100^{\circ}$	44	7	5	2	0	0	0	0	0	0	0	2	4	20
" $\geq 90^{\circ}$	44	18	15	10	3	0	0	0	0	0	3	9	16	74
" $\geq 36^{\circ}$	10	0	0	0	0	0.7	2.3	3.6	3.2	0.9	0	0	0	10.7
<i>Salmon Gums</i>														
Mean maximum	14	85.4	84.5	81.4	73.9	66.9	62.2	60.6	63.3	69.0	73.7	79.8	83.5	73.7
Mean minimum	14	56.0	55.7	54.8	49.0	43.8	41.4	39.1	40.2	41.8	44.9	49.5	53.4	47.5
Highest	24	114.0	110.0	108.5	102.0	90.0	89.9	90.6	81.9	96.0	101.7	105.3	109.2	114.0
Lowest	24	38.6	37.6	34.0	29.2	27.5	22.5	24.3	23.6	24.0	27.0	30.0	34.7	22.5
Average number $\geq 100^{\circ}$	12	3	2	1	0	0	0	0	0	0	1	1	2	10
" $\geq 90^{\circ}$	12	10	7	6	1	0	0	0	0	0	2	5	8	39
" $\geq 36^{\circ}$	—	0	0	0.2	0.8	2.9	6.2	9.9	7.3	5.9	4.4	0.5	0	38.1

52,149 acres at the Johnston Lakes were taken up from 1955-1957 with the intention of utilizing country where the woodland has a saltbush understory. The leases were abandoned due to lack of water supplies. There are settlements along the goldfields lines of communication across the north and east of the Boorabbin sheet, but these are not agricultural and have effected virtually no clearance of the plant cover. There has been mining development in the Coolgardie system, but this likewise has effected virtually no clearance of the natural vegetation. All mines are closed down at the time of writing. There is no longer any Aboriginal population in the area.

On the other hand, woodcutting has been in progress steadily for many years to provide mining timber and firewood for the goldfields and water pumping stations. More or less all the woodland in the eastern half of the Boorabbin sheet was cut over at one time, working from tram lines which no longer exist, but are shown on the geological map. Most of the woodland

TABLE 3
Diurnal Variation of Prevailing Wind

Hour	Number of Years	Southern Cross											
		Direction											
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0600	5	SE/S	SE/S	SE/S	SE/S	N/NE	N/NW	NW/W	NW/W	W/NW	SE/S	SE/S	SE/S
0900	5	NE/N	NE/N	NE/N	NE/N	NE/N	N/NE	N/NE	W/NW	NE/N	NE/N	NE/E	NE/E
1200	5	N/NE	N/NENE	N	N/NENE	N/NE	N/NE	NW/W	W/NW	W/SW	W/SW	W/SW	N/NE
1500	5	SW/W	SE/S	NE/N	NE/N	W/SW	N/NE	W/SW	W/NW	W/NW	W/SW	W/SW	S/SW

The wind data are of interest in view of the attention drawn by Sofoulis (1963) in the geological memoir to the elongation of the playa lakes in a NNW-SSE direction with an apparent migration of the lakes to the NNW and piling up of sand on the SSE side. During winter, the rainy season when the lakes may contain water, westerlies predominate and nearly all the strong winds (>20 knots) are from the north-west quadrant. This would account for the transport of sand to the south-east, and it must be assumed that the wave motions set up tend to form sandy beaches on the SE and to undercut the banks in the NW, even though at first sight the opposite would seem likely to be the case.

on the remainder of the Boorabbin sheet is now being tapped by motor truck working from roads running south from the Great Eastern Highway. The Lake Johnston sheet on the other hand is much more remote and untouched, and timber getting is confined to a belt about 10 miles wide along the southern half of the eastern margin of the sheet. Fellings which are very selective have had the effect of making the woodland more open. Regeneration seems generally to be satisfactory from seed except in *Eucalyptus salmonophloia* stands where it may be very slow to appear.

While human land utilization pressure in this area is minimal, it is quite another matter with that other anthropogenic factor, the bush fire. All large contiguous areas of scrub, thicket and mallee show burn patterns in air photographs, so much so that interpretation is often difficult. The taller sclerophyll woodlands burn only rarely and with difficulty if at all, owing to the sparseness of the ground layer and openness of the tree canopy, but the much denser shrublands burn all too easily. In the south, where woodland is shorter and denser and merges into mallee, it, too, will burn readily and there may be difficulty in distinguishing on photographs between mallee and burnt woodland. We can be certain that fire has occurred since time immemorial in this vegetation, at least as far back as the earliest

human occupation, but the probability seems to be that it has become more frequent since the arrival of Europeans. Burn patterns show recent fires to have started on roads and tracks, or to have spread from settled country in the direction of Southern Cross. Sofoulis (1963) has drawn attention to features detectable in burn patterns in aerial photographs which he describes as "sandplain lineaments", and attributes to lines of taller vegetation representing some source of underground water supply such as faults and joints in the underlying rock. It is difficult to subscribe to this view since the patterns radiate fanwise from the source of origin of a fire and extend along the direction in which the fire has moved most rapidly. Further, in the sandplain country the underlying rock is deeply buried and unlikely to affect surface vegetation. However, this is something that requires further investigation.

DESCRIPTION OF THE VEGETATION

Plant Formations

The Plant Formations occurring in this area are only six in number. Describing them in the simplest terms only, they are as follows:

1. *Scrub Heath*: Popularly "sand heath" or "sand plain", a mixed, stratified, partly open shrub assemblage with Proteaceae and Myrtaceae prominent, found on leached sands.

2. *Broombush Thicket*: Popularly "tamma scrub", a less diverse single-layered very dense shrub assemblage consisting mainly of *Casuarina*, *Acacia* and *Melaleuca* species, found on shallow sandy soil underlain by laterite ironstone and gravel, or by unweathered granite.

3. *Rock Pavement Vegetation* consisting of lichen and moss on soil-less outcrops of granite, with aquatic plants in pools and shrubs in crevices or occasional soil patches.

4. *Mallee*: Open to closed eucalypt shrub assemblage with variable low shrub ground layer, found on leached granite soils in the south of the area.

5. *Sclerophyll Woodland*:

(a) Mixed sclerophyll woodland, a medium-tall (40-50') open eucalypt woodland occupying eluvial soils in the north of the area.

(b) Salmon Gum woodland, tall (> 60') open eucalypt woodland occupying alkaline alluvial soils throughout the area.

6. *Halophytes*: Communities of succulent or more or less succulent subshrubs occupying highly saline depressions.

All of these formations are well developed upon the acid rocks which underlie the greater part of the area. Where there are outcrops of basic rocks, formations of 5(b) and 6 continue to occur as before on alluvial soils, 1, 3 and 4 are absent, while 2 and 5(a) occur with a distinctly different floristic composition.

It will be observed that two different terms, "scrub" and "thicket" have been used for shrubland formations, and this demands a word of explanation. Just as it is useful to distinguish between closed and open tree-dominated formations as "forest" and "woodland" respectively, so it seems necessary to distinguish in the same way between closed and open shrublands as "thicket" and "scrub". "Mallee", the eucalypt shrubland which has physiognomic properties of its own, should strictly be referred to as "mallee scrub".

Physiognomy

1. Scrub Heath

It is difficult to describe a characteristic structure for this formation, since the vegetation is burnt so frequently that a mature structure has little chance to develop. On regeneration after fire by coppice and seedling growth, a layer of low shrubs appears, at first open and then more or less closed. With further growth the naturally taller species begin to outstrip the smaller, and stratification begins to develop into a lower layer of small ericoid shrubs with emergent taller species with larger leaves. In time the upper layer, while remaining irregular due to the varying mature sizes of its components, may tend to close up and partially suppress the lower layer. The latter grows from 1–2½ ft in height, its components typically belonging to the Myrtaceae, with leaves leptophyll in *Raunkiaer* size. Some of these have a corymbose habit of growth, others are erect, thin and straggly. The components of the upper layer may reach 15 ft in height, belong typically to the Proteaceae and have very deeply divided, harsh, prickly leaves which are difficult to assess for leaf area but would be mainly microphyll in *Raunkiaer* size. There is some admixture of *Casuarina* from the adjacent thicket formation and low mallees tend to occur where there is some clay in the subsoil. All components are evergreen, with simple (though in many cases deeply divided) leaves. There is scope for considerable further investigation into the life form of scrub heath plants, their regeneration after fire and other aspects.

The structure is illustrated in the diagrams of Fig. 3, which are drawn from actual measured strips 50 ft long, 10 ft wide and represent what appear to be early and later stages of development. In the "early" stage

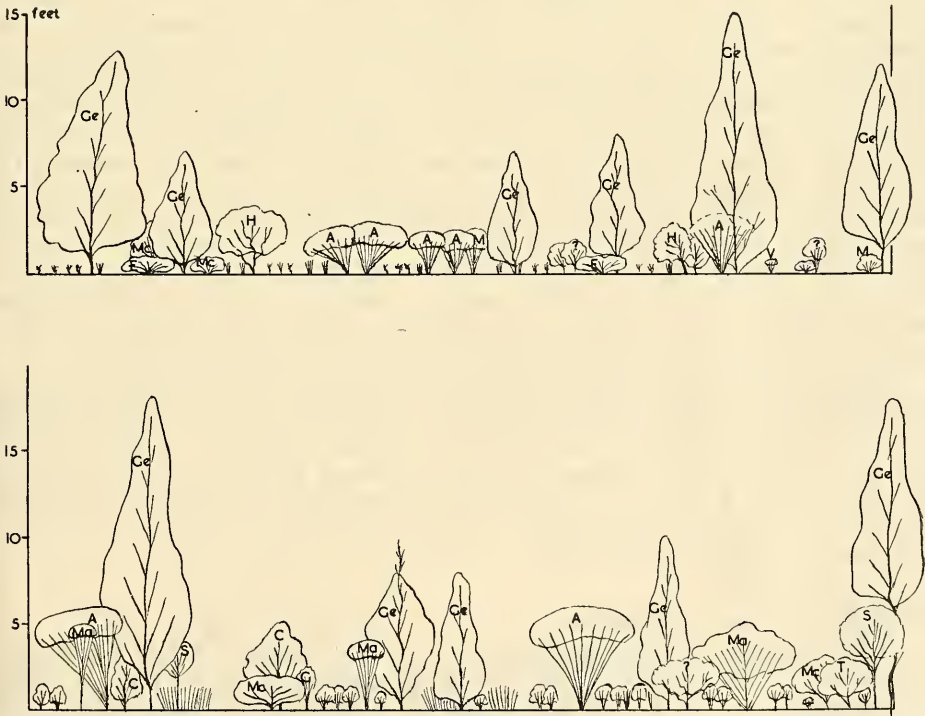


Fig. 3. Profile diagrams of Scrub Heath. Top—early stage. Bottom—late stage. Both near 255 mile peg, Hyden—Norseman Road. For key to species see p. 257.

the tall, pyramidal *Grevillea excelsior* shrubs have reached 10 ft–15 ft in height and a lower layer of 2–3 ft high shrubs has become established, interspersed with small clumps of sedge, small caespitose aphyllous plants and prostrate woody plants such as *Balaustion pulcherrimum* and *Borya nitida*. In the “later” stage many of the *Grevillea* are much taller, and all of them are beginning to show signs of senility. One in the left centre of the profile is recorded as stagheaded. Broombrush *Acacias* and *Melaleucas* have grown up to 6 ft in height, and there appears to be invasion in progress by *Callitris preissii*, *Santalum acuminatum* and a *Hakea* sp. In the vicinity of this profile but not recorded in it, other such invaders were observed to include *Hakea multineata*, *Calothamnus quadrifidus* and *Casuarina corniculata*. The supposed invaders are all relatively young plants of species which are known to become much larger. It seems probable that *Grevillea excelsior* is a pioneer species in scrub heath following fire and that a succession can be recognized. The ground layer of the “later” stage differs in that there are large and well established sedge clumps, with numerous small ericoid shrubs of 1–1½ ft.

2. Broombush Thicket

In its purest form the thicket is a dense, closed, single-layered community of relatively simple floristic composition. It grades, however, very gradually into scrub heath where the two adjoin, so that there are intermediate structures such as the addition of a ground layer of small ericoid shrubs. Like the scrub heath the thicket is subject to frequent fires by which it is destroyed, regenerating from seed. Height of the vegetation therefore depends largely on the time that has elapsed since the last fire, up to 12 or 15 ft being possible. Where undershrubs occur they naturally will flourish mainly in the early stages, becoming suppressed later. The dominant components of the thicket are virtually confined to different species of *Casuarina*, *Acacia* and *Melaleuca*, all of which have the same habit of growth: the stem divides repeatedly into a large number of thin, largely erect branchlets terminating at the same height and giving a dense, gently domed crown to the bush. This may be referred to as the “Broom-bush” habit. It is perhaps analogous to the mallee habit of eucalypts. In *Casuarina* leaves are reduced to scales and their function taken over by the thin, terete, green twigs. The fruits are held on the bush until it dies or is killed by fire, when seed is liberated. The *Acacia* species have phyllodes, narrow, linear and about 2 in. long. The seed is shed but is protected by a hard seed coat: germination takes place copiously after burning. *Melaleucas* have small ericoid leaves and their fruits behave like those of *Casuarina*.

Two profiles have been measured to illustrate the structure of this formation and appear in Fig. 4, being an “early” and “late” stage as in the case of the heath scrub. There is no essential difference except that the virtually closed canopy formed already at about 4 ft in the “early” stage has advanced to 8 ft in the “late” stage. Heath components such as *Banksia*, *Hakea* and *Isopogon* have grown rather less in height and are becoming suppressed by the broom-bushes.

3. Rock Pavement Vegetation

The numerous bare outcrops of granite rock, devoid of soil, throughout this area, are for the most part unable to support any plant cover except aquatics in rock pools and some thin crust of lichen. Accumulations of peaty matter may occur in hollows, which support low woody plants and shrubs.

4. *Mallee*

Mallee is a shrub-eucalypt formation. Each plant has an underground rootstock about one cubic foot in size from which arise numerous slender stems giving a bushy crown similar to the "broom-bush habit". Mallee is subject to frequent fires which destroy the top growth, regeneration taking place from coppice. It is not clear to what extent the mallee habit is genetically controlled or due to fire. Certainly any small eucalyptus tree of a species having the power to coppice would automatically assume



Fig. 4. Profile diagrams of Broombush Thicket. Top—early stage. Bottom—later stage. Top—285 mile peg, Hyden - Norseman Road. Bottom—233 mile peg. For key to species see p. 257.

a mallee habit if frequently burnt, and very many mallee species can also be found in tree form, either moderately sized or in the small but single-stemmed tree form known as "marlock" in Western Australia. The structure of mallee is extremely variable, its height varying with age from the last fire, and its density and associates varying also. The most typical form of mallee is a closed community of mallee habit rising from 10–15 ft in height with an understory of small ericoid shrubs of the genus *Melaleuca*. The understory may elsewhere consist of mixed shrubs belonging to the heath scrub where there is a transition to the latter formation, of salt-bush under alkaline soil conditions or of hummock-grass on red sand. In this area the last two types occupy only small patches which are not mappable. The same species of mallee eucalypts may occur over different understories and vice-versa, and the stature of the eucalypts may vary without change of species from true mallee to marlocks and small trees. Profile diagrams measured in mallee are presented in Figs 5 and 6, the former a low form



Fig. 5. Profile diagram of low Mallee, 254 mile peg, Hyden - Norseman Road. For key to species see p. 257.

and the latter a tall. It is believed that these represent early and late growth stages. In both cases the mallee forms an almost closed canopy layer, at 7 ft and 20 ft respectively, with a discontinuous lower layer of *Melaleuca* broom-bushes. Occasional small clumps of grass were the only ground vegetation in both cases.

5. Sclerophyll Woodland

Like the mallee, the sclerophyll woodland is eucalypt-dominated, there are several different floristic associations and structural types. In general, growth consists of a tall but open stand of trees with extremely sparse undergrowth with the result that the woodland is subject to burning to only a minor extent. Where fire passes, the trees are killed and do not coppice but regenerate from seed, an even-aged stand resulting. Study is required of the extent to which existing stands are even-aged, and of the regeneration of the various species. If it should prove that fire, even at

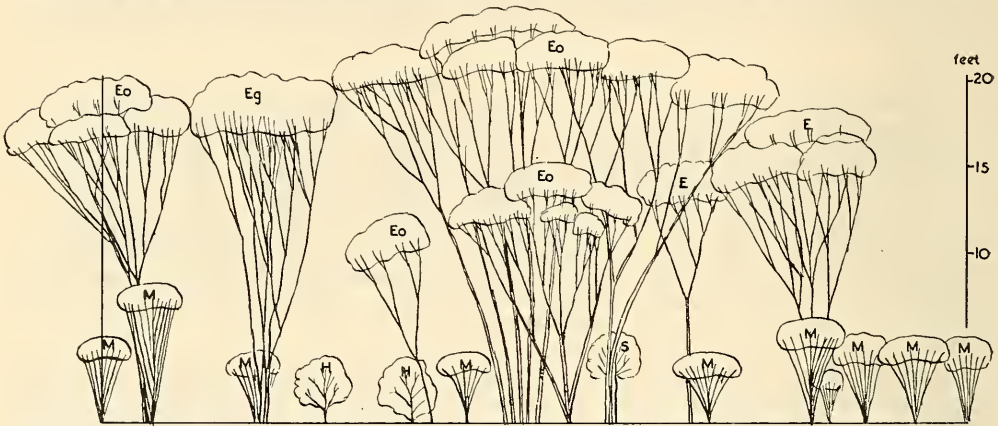


Fig. 6. Profile diagram of tall Mallee near 260 mile peg, Hyden - Norseman Road. For key to species see p. 257.

very long intervals, is the agent responsible for regeneration of these woodlands, then as with the other formations height and density are a function of age and structure is not altogether meaningful. There is in general a correlation between height and density in that the lowest woodlands tend to be the densest, and the tallest the most open. There is every gradation from the low dense mallee to the very tall stands of over 80 ft in height where the trees are extremely scattered. However, one may distinguish two broad classes, the mixed woodlands of 40-60 ft in height on residual soils, and the Salmon Gum (*Eucalyptus salmonophloia*) woodlands of alluvial flats, which exceed 60 ft. In the former type trees are irregularly scattered so that in part their crowns touch and in part there are large open spaces. Diameters of the dominants are 9-12 in. The trunk forks into a number of ascending branches at about a third of tree height and the rather flat crown is thin and casts little shade as the leaves hang downwards. Except at times in gaps the only tree layer is that of the dominants forming the canopy, but there are two highly sparse layers of shrubs, the one 6-12 ft high and mainly of "broom-bush" habit, the other of low shrubs under 2 ft. Locally the latter may be saltbush. On soil derived from granite the trees in this formation are smooth-barked, but on basic rocks the majority of the species have persistent rough bark on the lower trunk or on the trunk and lower limbs. The significance of this is not understood. Fig. 7 illustrates a measured profile in an example of this mixed woodland in which *Eucalyptus*

transcontinentalis is dominant. One outstanding tree reaches 75 ft in height, but most of the dominants attain between 40 and 60 ft. There is an understory of eucalypts in mallee form. Low shrub and herb layers are virtually absent. The profile demonstrates the irregularity of the woodland and the openness of the canopy. There are wide gaps between groups of dominants which

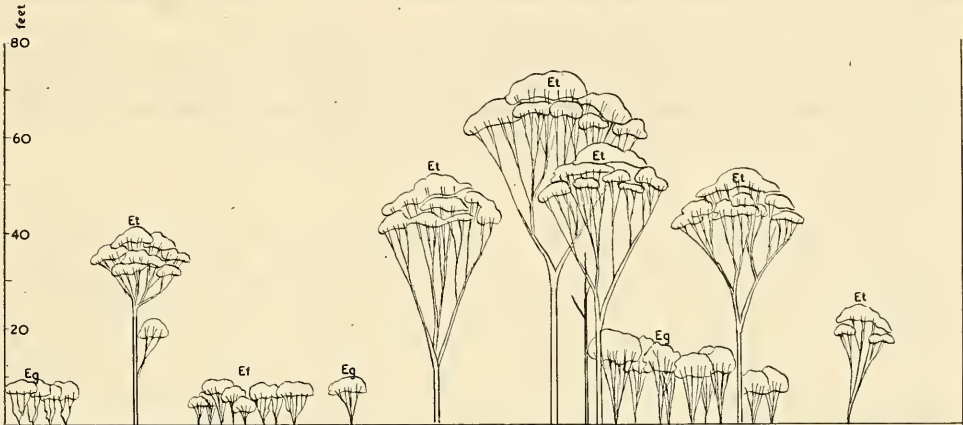


Fig. 7. Profile diagram of sclerophyll woodland—*Eucalyptus transcontinentalis*. For key to species see p. 257.

tend to occur in clusters, the result no doubt of group regeneration. Much more work could usefully be done on the structure and stability of these woodlands.

The taller woodland of *Eucalyptus salmonophloia* and its associates is generally over 60 ft tall, with a maximum of about 90 ft, very open with the trees as much as 200 ft apart. There is a very strong trunk, in most cases up to 3 ft in diameter and extending to half the height of the tree. The shrub layers are as in the mixed woodland, a saltbush understory being common in the vicinity of salt lakes and on alluvia derived from basic rocks. Both smooth and rough-barked trees are present but, as before, the rough bark appears to indicate a higher base status in the soil.

Fig. 8 shows a profile measured in pure salmon gum woodland, an example which is probably of a denser stand than normal (compare



Fig. 8. Profile diagram of sclerophyll woodland—*Eucalyptus salmonophloia* association measured 26 miles south of Hyden on Hyden—Newdegate Road. For key to species see p. 257.

photograph). Density is frequently irregular and clustered as with the *Eucalyptus transcontinentalis* woodland, and a typical group occurs in the centre of the measured profile. Height of the dominants is generally greater than that of *Eucalyptus transcontinentalis* and its associates. Seedlings, saplings and young pole-sized *Eucalyptus salmonophloia* are a rarity, but there is very frequently a tall shrub layer of the *Melaleuca* species known as "Boree".

In all the eucalypt types including mallee, the adult leaves are evergreen, simple, mesophyll in Raunkiaer size, falcate and pendant, hanging vertically. There is a complete absence of lianes and epiphytes, and of any such special plant forms as palms, cycads and bamboos, even grass trees.

6. Halophytes

The most extreme communities of halophytes are the small (< 12 in.) succulent chenopodiaceous shrubs which occupy raised beds on the floors of the larger salt lakes. Rather rarely here, one may find a *Frankenia* zone of small ericoid shrubs round the lake margin. Alluvial flats bordering lakes tend to have a saltbush understory in woodland and in some places on the north-east side of a lake the tree cover may be very sparse or virtually absent, leaving a pure saltbush community. Sandhills to the south-east of lakes tend to carry a woodland of special floristic composition which is described in the appropriate place, but has not been mapped. Halophyte communities have otherwise been mapped where they occur.

Classification, Terminology and Notation

The broad principles of classification adopted are those stated by the author in previous work (Beard, 1944, 1955). To recapitulate briefly, the basic unit is the plant association which is a floristic grouping, being the largest possible group with consistent dominants, either of the same or closely allied species. Associations may be divided into minor floristic groups, to which it was proposed to apply the Clementsian terminology. Also they may be termed consociations if they are single-dominant communities. The associations may be grouped together according to their physiognomy (structure and life-form) into formations. The formation is thus a physiognomic group and can be treated without reference to floristics. A higher grouping of formations into formation-series was proposed by Beard for tropical America (*ibid.*) and the applicability of this concept to Australia is discussed below.

Coming down from principles to practical considerations, there is a need for some consistent and logical system of classification, some consistent terminology and a mapping notation, for use in the description of vegetation and in the cartography. On the other hand it is not possible to predict accurately in advance of a survey what vegetation units are going to be found in Western Australia, and how they need to be treated. In a general way, of course, the vegetation types of the State are known, but it would be unwise to adopt a rigid classification and terminology in advance. It would be better to consider this towards the end of a general survey and to adopt in the meantime a flexible system. It is therefore proposed to distinguish plant formations by local names, e.g., jarrah forest, mallee, mulga and pindan, and to relate these in each paper as they occur to recognized classification systems.

At the highest level of classification we have the system put forward by Küchler (1949) and elaborated by Dansereau (1951) which was designed to be of universal application on a world scale and to facilitate valid

comparisons between vegetation units in different parts of the world. A recent paper (G. Ross Cochrane, 1963) has applied a slightly modified Kùchler system to the description of Australian vegetation types on a continental scale. There have been other cases in different countries where the Kùchler system has also been applied and it seems desirable that we should also participate. For the benefit of those interested in comparative vegetation on a world scale it is proposed to give both Kùchler and Dansereau notations, and Dansereau diagrams, for our vegetation types in descriptive memoirs, though in point of fact the value of this where Australian vegetation is concerned may be questioned. Comparisons are valueless if not valid, and it may be objected that Australian vegetation has so many unique features unrepresented elsewhere that comparisons between it and other world vegetation may not be valid at all. The fundamental idea behind methods of description and classification designed to be of universal application is that vegetation is the expression of environment and that if we can equate vegetation units in different areas we can be assured that they express (within narrow limits) the same environment. This, however, may very well be a false assumption when totally different floras are involved in the comparison and it is strongly suspected that this point will be proven when more exact physiognomic comparisons between Australian and other vegetation become possible. At least by stating our vegetation types in Kùchler and Dansereau terms we are making a contribution to such study, and it can be done without proclaiming any faith in the outcome of it.

Both Kùchler and Dansereau, followed by Ross Cochrane, have spoken of their systems as "classifications", but they are in effect descriptive notations. A classification would appear rather to be an ordered system of arrangement of vegetation types linked to a terminology, both of which serve to emphasize and clarify the relationships and differences between these types. In this sense, a genuine classification of Australian vegetation types is of the kind published by Williams (1955), with its physiognomic key and its terminology based on kinds of forest, woodland, savannah and so on. There appears to be no generally accepted and satisfactory system of classification for Australian vegetation, but Williams seems to have been the closest to approach the goal. His treatment contains some inconsistent features and may not in the long run be workable without modification, but it may be accepted provisionally and any difficulties can be discussed as they arise.

In addition to these arrangements for classification and terminology, we require for use on maps a notation system similar to that employed by geologists, e.g., Ts, tertiary sandstone; Ag, Archaean granite. In our case the notation should be of reasonable brevity and should if possible convey the diagnostic features of the vegetation which are:

1. Nature and size of the dominant stratum and of other strata if of diagnostic importance.
2. Dominant or diagnostic plant species.
3. Density of the strata referred to in 1.

It should be possible to arrive at a 3-letter notation to embrace the above. A mapping notation must above all be brief and long alphabetical formulae which are involved in Kùchler's system, and even more so in Dansereau's, are too cumbersome. The only Australian community cited by Dansereau (1951), that of *Ceratopetalum australiense*, has the formula Tteazc.Ltehz.B.Etegx.Ftevc.Hmevzb. and even Kùchler's much simpler system still produces Tropical Rain Forest = Btml.ejuy.Hlmp. These could never

appear on any map and it is unlikely that it was ever intended that they should, the purpose being symbolic description of vegetation, rather than mapping. However, it is possible to borrow from K  chler and Dansereau in the construction of a simpler system as follows:

1. *Physiognomy of Dominant Stratum*

T	Tall trees > 25m. tall
M	Medium trees 10-25m. tall
L	Low trees < 10m. tall
S	Shrubs > 1m. tall
Z	Dwarf shrubs < 1m. tall
G	Graminoids other than spinifex
H	Hummock grass (spinifex)
F	Forbs
X	Lichens and mosses (Hepatics)
C	Succulents (Chemopods)
T _d	Tall deciduous trees
M _d	Medium deciduous trees
L _d	Low deciduous trees

2. *Floristic*

e	Eucalypt
a	Acacia
t	Triodia
x	Heterogeneous (mixed or other)

(To be differentiated as e_1 ; e_2 for individual species. Other species may be added as required, e.g., m = *Melaleuca*.)

3. *Density*

c	Closed or continuous
i	Open, not touching; incomplete cover
p	Scattered groups
r	Rare but conspicuous
b	Barren — vegetation largely absent

The actual formulae are to be written with the floristic category first, e.g., eMc; aLi meaning respectively a eucalypt-dominated closed medium tree community (a eucalypt forest in fact) and an acacia-dominated woodland (mulga). The formulae are designed in this "triangular" form in order to be more readily comprehended at a glance. The central capital letter conveys the most important feature, physiognomy; the left hand one floristics and the right hand one density. This may be found aesthetically more pleasing, and more efficient, than the usual formula beginning with a capital and tailing off into a string of small letters whose order and position may often be confusing.

The principal, capital-lettered category, is based upon K  chler's group 1: Height, and is intended to accord mention primarily to the dominant stratum, e.g., eMc. If two or more strata are considered co-dominant, their symbols may be written together, e.g., xSZi. Any diagnostically important strata may be included in this manner—eLr.aSr.pHi—which is the formula for sandhill desert, i.e., an open Hummock-grassland of *Plectrachne* with scattered acacia shrubs and low eucalypt trees. It is not intended, however, to deal exhaustively with all synusiae in the manner of Dansereau. This is a mapping notation which sets out to describe salient features only.

The floristic category serves to name the species or genera which are dominant or diagnostic, but as most West Australian communities are of simple composition or even single-dominant associations, this category will also to a large extent convey — from the known morphology of the species — a life-form characteristic of the community. In Australia a relatively few genera dominate and provide a characteristic form for whole communities in this way — *Eucalyptus*, *Acacia* and *Triodia* (or *Plectrachne*), rather more rarely *Melaleuca*, *Casuarina*, etc. A category “heterogeneous” is provided for mixed communities in which no definite dominance asserts itself. The actual species concerned may be nominated if desirable by subscript numbers. This category is basically the same in conception as Kùchler’s initial one, which he writes in capitals, using the classes evergreen broadleaf, deciduous broadleaf, evergreen needleleaf, etc. These were obviously designed for a North American environment and represent basic life-forms to a large extent characteristic of taxonomic groups, e.g., conifers and angiosperms. In Australia life-form is even more closely related to taxonomic groups and at a lower level. If a community is said to be eucalyptoid, acacioid or triodioid a characteristic life-form is at once conveyed to the reader.

The third category “Density” is the same as Kùchler’s Group II. Kùchler’s Group III is not directly included: the characters which it deals with will have been already incorporated in our series if important, i.e., if they are “salient features”, otherwise they are disregarded. Dansereau has set up three other categories in his system, Function, Leaf Shape and Size, Leaf Texture. All of these will be found to be conveyed by our first category Floristic and are therefore not separately required. There are presented here first a number of actual profiles of vegetation (Figures 3–8), secondly “Dansereau diagrams” (Figures 9–13) in which these diagrams are converted into pictograms according to the method of Dansereau (1951) and thirdly a series of comparative formulae according to the system of notation proposed above and those of Dansereau (1951) and Kùchler (1949) in Table 4.

TABLE 4

Plant formations of the Boorabbin-Lake Johnston area	Beard formula	Kùchler formula	Dansereau formula
Scrub heath	xSZc	Bszc	Fteaxi.Fmeaxe
Broombush thicket	cSc	Bsc	Fmejaxc
Rock pavement vegetation	xXi	Li	Mljgki
Mallee	eSZc	Bszc	Fleaxe.Fmeaxe
Sclerophyll woodland	eMi	Bmli.szr	Tmeaxi.Fmleaxb
Halophytes	xCi	Oik	Fljgki

KEY TO SPECIES APPEARING ON DIAGRAMS

A *Acacia*; B *Banksia elderana*; C *Callitris preissii*; Ca *Casuarina acutivalvis*; Cs *Casuarina campestris*; Cc *Casuarina corniculata*; Er *Eremaea pauciflora*; Ef *Eucalyptus flocktoniae*; Eg *Eucalyptus gracilis*; Eo *Eucalyptus oleosa* var.; Es *Eucalyptus salmonophloia*; Et *Eucalyptus transcontinentalis*; E *Eucalyptus* species unidentified; G *Goodenia* sp.; Ge *Grevillea excelsior*; H *Hakea*; I *Isopogon scabriusculus*; Ma *Melaleuca acuminata*; Mc *Melaleuca cordata*; Mp *Melaleuca pauperiflora*; M *Melaleuca* sp. unidentified; S *Santalum acuminatum*; T *Thyrtomene*; V *Verticordia*.

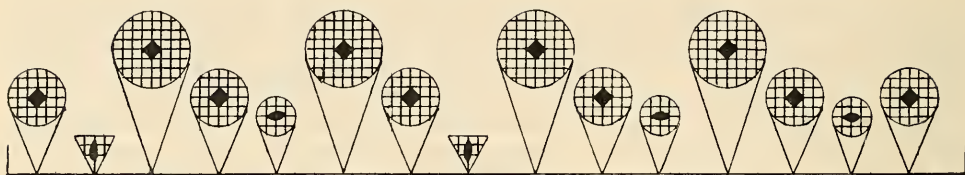


Fig. 9. Dansereau diagram for Scrub Heath.

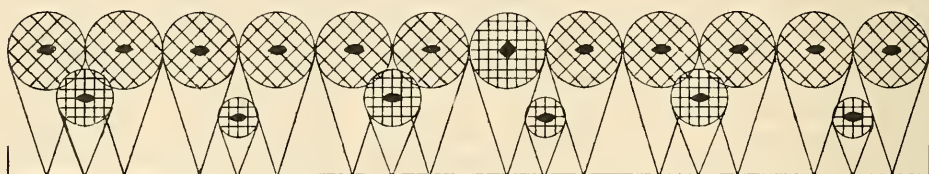


Fig. 10. Dansereau diagram for Thicket.

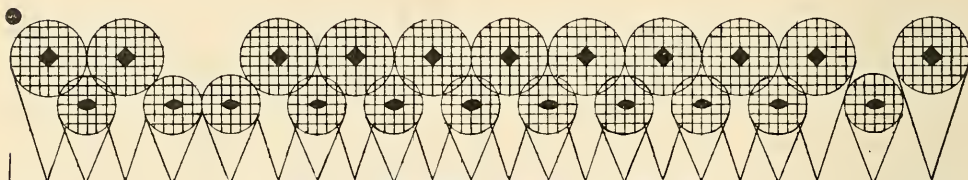
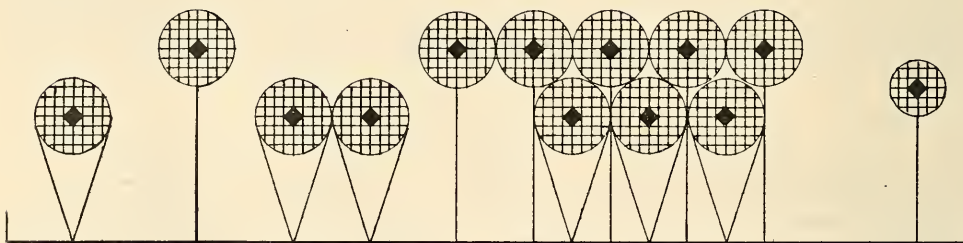
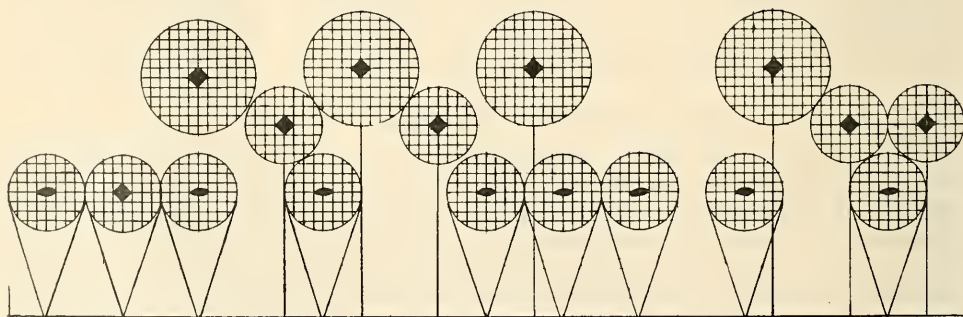


Fig. 11. Dansereau diagram for Mallee.

Fig. 12. Dansereau diagram for sclerophyll woodland *Eucalyptus transcontinentalis* - *E. flocktoniae* association.Fig. 13. Dansereau diagram for sclerophyll woodland - *Eucalyptus salmonophloia* Association.

VEGETATION SYSTEMS

Beard's work in Tropical America (1944, 1955) based primary classification upon floristics (the plant association), secondary classification upon structure and life-form (the plant formation) and a tertiary classification upon habitat (formation-series). At the tertiary level, five series of related formations could be built up with descending structure radiating from an optimum, each series within the same general kind of environment or "essential habitat", their descent reflecting decreasing availability of moisture or other comparable factors. Under Australian conditions, while this approach may still be fruitful for certain purposes and in a fuller state of our knowledge, it would appear at present that for vegetation survey a regional approach analogous to the Land System classification used by the C.S.I.R.O. (e.g., Speck 1960; Mabbutt 1963) would be more immediately valuable.

A Land System is defined (*loc. cit.*) as an "area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation", and all three aspects of the landscape, together with geology and climate, are studied and interwoven into Land Research work. A vegetation survey, like a topographic, soil and geological survey, studies one aspect in particular with reference to the others, but the same recurring patterns will be observed and can be used to characterize unit areas. A vegetation survey will be expected to discover such patterns which will be dependent upon topographic and/or soil features, in the same way that it is already accepted practice for a soil survey to recognize recurrent patterns of soil types dependent upon topographic and/or geological features and characterized by distinctive vegetation. Working in East Africa, Milne (1935) discovered that soil types recurred in a definite position according to slope and originated the concept of the soil catena. Since that time the catena with modifications has come into general acceptance in British soil survey work. The Soil Survey of Scotland uses the Soil Association, a term originated by J. H. Ellis in Canada in 1932, which is a drainage catena. The term Soil Catena is used in the Soil Survey of England and Wales for a "sequence of repetitive soil series which recurs in a manner dependent upon topographic features" (Clarke, 1937), but it is the practice to speak of Soil Mosaics where the patterns are not topographically controlled. In the light of existing C.S.I.R.O. Land Research work in Western Australia, it can be confidently expected that as the Vegetation Survey proceeds patterns of vegetation will emerge closely corresponding to soil catenas and mosaics which will be termed catenary sequences of vegetation and vegetation mosaics. It may be expected that catenary sequences will predominate on the interior plateau and mosaics, possibly, on the coastal plains.

It will be desirable to recognize unit areas within which the same patterns recur, and to find a term for these. Although these are geographical areas, in a vegetation survey they rank as vegetation units. They are not, therefore, land systems, though it may logically be expected that if complete land research comes to be done the vegetation of the area will be found to be the vegetation of a co-extensive land system. We have in this case had to search for a term for our own use. The term Soil Association suggests Plant Association as an equivalent, but this is pre-empted for plant communities at a lower level of classification corresponding to Soil Type. "Vegetation System" seems to be the best choice of term. Since we have already from Diels, Gardner and Bennetts a division of Western Australia into Botanical Districts and Provinces, it will probably be the most convenient to regard Vegetation Systems as subdivisions of districts. As the Survey

builds up, the boundaries of the Districts and Provinces, which are at present highly generalized, will become more exactly defined, and this itself is a desirable objective.

The relation between the classification adopted in the Vegetation Survey of Western Australia for vegetation units and major world systems of soil classification would then become as follows:

TABLE 5

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Vegetation classification	Faciation, society, etc.	Plant association (floristic)	Plant formation (physio-gnomic)	Vegetation system	Botanical district	Botanical province
U.S. Soil Survey classification	Soil phase or variant	Soil types	Soil series and soil complex	—	—	—
British Soil Survey	Subtype	Soil type	Soil series and soil complex	Soil Association (Scotland) Catenas and mosaics (England)	Major region	—
Russian Soil Survey	Soil individual	Soil variety	Soil Complex	Elementary Landscape	Soil Region	Soil Province

As indicated in the section on Physiography, it is possible to recognize five vegetation systems in the area studied.

1. The Boorabbin System

At the highest points and in the centre of the widest interfluves, broad plateaux of deep yellow sand carry a pure scrub heath association. For several months in the spring this type is filled with brilliantly flowering plants of all colours. Down slope it merges very gradually, so that sharp boundaries can never be drawn, into the broom-bush thicket. There is at first a general mixture then heath plants are relegated to an understory and finally disappear. Within these two zones outcrops of granite occur, with their rock pavement vegetation. Down slope under the broom-bush scrub the yellow sand becomes shallower and is bottomed by a lateritic hardpan which eventually comes to the surface often with a small scarp or "breakaway". Below this there is an abrupt change to sclerophyll woodland, at first the mixed association of *Eucalyptus transccontinentalis* and *Eucalyptus flocktoniae* on a relatively shallow red loam soil overlying granite. Further down in the valley bottom on deep alluvium there is a gradual change to the taller *Eucalyptus salmonophloia* association. The latter species is general throughout on light loam. *Eucalyptus longicornis* comes in on heavier soil, *Eucalyptus salubris* on stiff clay and *Eucalyptus melanoxylon* where kunkar is abundant.

2. The Cave Hill System

In the Cave Hill System there is very little scrub heath due to dissection of the sandy plateau surfaces. The interfluves are mainly characterized by granite outcrops surrounded by thicket growing on shallow decomposing rock or residual ironstone. On the lower ground the same woodland types are found as in the Boorabbin system.

3. The Lake Hope System

Here there is a relative scarcity of both scrub heath and thicket with their associated plateau soils. Instead the uplands are covered with the mallee formation with its typical sand over clay profile. On lower ground this merges patchily into very variable mixed woodland, variable both in structure and composition between the extremes of mallee and typical woodland. There is much less of the *Eucalyptus salmonophloia* type in this system and it tends to become restricted to "reefs" or narrow belts mainly in valley bottoms, but also at times on higher ground.

4. The Coolgardie System

This system is mainly developed in the Eastern Goldfields area to the north-east, and a relatively small portion of it only is included in the north-east corner of the Boorabbin sheet. The component communities are mainly sclerophyll woodland with some mallee and broombush thicket. The basic rocks or greenstones tend to form small, hilly ranges, in which the highest and stoniest hills are covered with broom-bush scrub mainly of *Acacia*, and the less rocky ridges with sclerophyll woodland of the *Eucalyptus torquata-Eucalyptus le soeufii* association. It is possible that the *Acacia* scrub maybe associated with rock of a particular lithological type. Woodland on the lower, less hilly and rocky ground corresponds in structure to the mixed *Eucalyptus transcontinentalis* woodland of the three vegetation systems on acid rocks described above, but is of quite different composition, characteristic species being *Eucalyptus le soeufii*, *Eucalyptus clelandii*, *Eucalyptus campaspe*.

The commonest of these are "blackbutts", that is, there is a persistent scaly bark on at least the lower part of the trunk, whereas on the acid rocks components tend to be smooth-barked. On low-lying alluvia the *Eucalyptus salmonophloia* association is found, with a preponderance of salt-bush in the understory. Occasionally on the higher ground there may be sandy plateaux, mainly on included granites, the sand being red in colour. On deep sand, in small patches, one finds mallee with spinifex, a mallee form of *Eucalyptus oleosa* with an understory of *Triodia scariosa*. Otherwise the plant cover of these plateaux is broom-bush thicket similar to that on acid rocks.

5. The Bremer Range System

While the Bremer Range is similar in geology and topography to the Coolgardie area its plant communities are entirely different. On the rocky knolls one finds a broom-bush thicket of *Casuarina* and a complete absence of *Eucalyptus torquata* and *Eucalyptus le soeufii*. In local patches the thicket breaks away to a grassland with shrubs. Footslope areas carry a fine sclerophyll woodland of *Eucalyptus dundasii* and *Eucalyptus longicornis* (both blackbutts), with no other associated trees except that where the woodland has been destroyed by fire the regeneration in addition to the above two species contains much *Eucalyptus corrugata*. The latter species appears to be relatively shortlived in competition with the others and under undisturbed conditions appears to be confined to a narrow belt between the woodland and the thicket. On low alluvial country there is the usual *Eucalyptus salmonophloia* association.

BOTANICAL PROVINCES AND DISTRICTS

From external evidence it would appear that the Lake Hope System, in which mallee is the dominant member of the catena, forms part of the Eyre District of the Southwestern Province, whereas the others belong to the Coolgardie District of the Southwestern Interzone.

FLORISTIC COMPOSITION

The purpose of this section is primarily to distinguish floristically the various plant communities recognized. To do this the names of dominant, diagnostic and common or conspicuous species have to be listed, but there is no necessity to aim at a complete list of components. This would only be the objective if a complete botanical survey were being undertaken. As it is, the plant lists are being made as complete as possible within the scope of our knowledge, but it should be understood that they are only collectors' lists and of necessity incomplete.

1. Scrub Heath

This formation is by far the richest floristically of any of those in the locality and is also without any definite and consistent dominants so that it is not at present possible to characterize associations within it. There is scope for interesting and useful ecological research in studying the composition of this formation in detail. All that can be said as regards dominance is that *Grevillea excelsior* and in the northern part *Grevillea pterosperma* may assume physical dominance by growing to a much greater height than other components and may at times be quite abundant. They are very conspicuous and thus tend to appear typical species although their occurrence is very irregular. On the other hand it is suspected that *Grevillea excelsior* is actually a pioneer species and is relatively short-lived, dying out a certain number of years after the fire which regenerated it and giving way to slower-growing, slower-regenerating shrubs. There is an indication of this in the profile diagrams, as discussed earlier.

Further, *Grevillea excelsior* is essentially typical of deep yellow sand and occurs sparingly if at all wherever ironstone gravel predominates. Here *Dryandra* or *Casuarina* replace it. There is no distinct boundary between the scrub heath on its yellow sand and the broom-bush scrub on its ironstone gravel, the two soils and the two vegetations merging into one another. The ecotone is characterized by a broom-bush upper layer with *Casuarina*, *Acacia* and *Melaleuca*, and a heath lower layer of small, ericoid, mainly Myrtaceous, shrubs. At an early stage after fire the latter is re-established and appears to be a similar early stage of pure scrub heath. Later, however, the broom-bushes grow up and suppress it and give the opposite impression. The character of the vegetation in the ecotone thus varies according to time elapsed since the last fire.

This process has been described also for the pure heath scrub when dealing with physiognomy. In the plant lists which follow, an attempt has been made to define those species which in matured scrub would form part of the upper layer, as distinct from those which remain part of the lower layer.

Mallees are found sporadically in the scrub heath and may often, as in the case of *Eucalyptus burracoppinensis* and *Eucalyptus leptopoda*, be typical of it and not found to occur in any actual mallee formation.

Composition of the Scrub Heath in the Boorabbin System

Tall emergent shrubs: *Grevillea excelsior*, *G. pterosperma*.

Upper layer: *Acacia beauverdiana*, *A. fragilis*, *A. hynesiana*, *A. resinomarginea*, *A. rossei*, *A. sterophylla*, *A. spp.* J.S.B.3353-4, *Banksia audax*, *B. elderana*, *B. sp. inedit.* J.S.B.3879, *Callitris preissii* subsp. *verrucosa*, *Casuarina acutivalvis*, *C. campestris*, *C. corniculata*, *C. dielsiana*, *C. helmsii*, *Dryandra* sp. J.S.B.3871, *Eucalyptus burracoppinensis*, *E. foecunda*, *E.*

incrassata, *E. leptopoda*, *E. platycorys*, *Grevillea apiculoba*, *G. biformis*, *G. ceratocarpa*, *G. didymobotrya*, *G. hookeriana*, *G. rufa*, *Hakea falcata*, *H. platysperma*, *H. roei*, *Isopogon scabriusculus*, *Persoonia saundersiana*, *Petrophile conifera*, *P. ericifolia*, *P. semifurcata*.

Lower layer: *Adenanthos flavidiflora*, *Baeckea leptospermoides*, *Balaustion pulcherrimum*, *Boronia ternata*, *Brachysema chambersii*, *Burtonia hendersonii*, *Calytrix breviseta*, *Chamelaucium pauciflorum*, *Conospermum brownii*, *C. stoechadis*, *C. teretifolia*, *Cyanostegia microphylla*, *Dampiera lavandulacea*, *D. luteiflora*, *D. stenostachya*, *Daviesia croniniana*, *Eremaea pauciflora*, *Erichsenia uncinata*, *Eriostemon brucei*, *E. coccineus*, *Goodenia pinifolia*, *Grevillea haplantha*, *Halgania tomentosa*, *Hemigenia dielsii*, *Hibbertia stricta*, *H. uncinata*, *Jacksonia hakeoides*, *Lachnostachys bracteosa*, *Leptospermum roei*, *Leucopogon* sp. J.S.B.3339, *Melaleuca cordata*, *M. holosericea*, *M. subtrigona*, *Microcorys ericifolia*, *Micromyrtus racemosa*, *Phebalium drummondii*, *Persoonia coriacea*, *Petrophile circinata*, *Pityrodia caerulea*, *P. lepidota*, *P. uncinata*, *Plectrachne rigidissima*, *Pultenaea georgei*, *Stylidium limbatum*, *Tetralthea efoliata*, *Thryptomene kochii*, *Verticordia chrysantha*, *V. insignis*, *V. pennigera*, *V. picta*, *V. pritzelli*, *V. roei*, *Waitzia acuminata*, *Wehlia thryptomenoides*.

Composition of the Scrub Heath in the Cave Hill and Lake Hope Systems:

Tall emergent shrubs: *Grevillea excelsior*.

Upper layer: *Banksia elderiana*, *B. laevigata*, *B. media*, *Callitris preissii* subsp. *verrucosa*, *Calothamnus quadrifidus*, *Casuarina acutivalvis*, *C. sp. C. microstachya*, *Dryandra erythrocephala*, *D. sp. J.S.B.3681*, *Dodonaea stenozyga*, *Eucalyptus eremophila*, *E. flocktoniae*, *Grevillea sp. aff. asparagoides*, *G. concinna*, *G. didymobotrya*, *G. hookerana*, *G. incrassata*, *G. integrifolia*, *G. rufa*, *G. teretifolia*, *Hakea falcata*, *H. multilineata*, *H. roei*, *H. subsulcata*, *Isopogon axillaris*, *I. scabriusculus*, *I. sp. inedit. aff. teretifolius*, *Petrophile semifurcata*, *P. seminuda*.

Lower layer (shrubs, subshrubs and herbs): *Adenanthos flavidiflora*, *Astroloma serratifolium*, *Baeckea crispiflora*, *Calythrix aff. decandra*, *C. breviseta*, *Casuarina humilis*, *Chamelaucium megalopetalum*, *C. pauciflorum*, *C. virgatum*, *Comesperma drummondii*, *Cyanostegia angustifolia*, *Dampiera juncea*, *D. lavandulacea*, *D. wellsiana*, *Eremaea pauciflora*, *Grevillea eryngioides*, *G. prostrata*, *Halgania integerrima*, *Hemigenia eutaxioides*, *Isopogon villosus*, *Leptospermum roei*, *Leschenaultia expansa*, *L. sp. inedit.*, J.S.B.3785, *Logania tortuosa*, *L. sp. inedit.*, J.S.B.3737, *Lysinema ciliatum*, *Melaleuca cordata*, *M. subtrigona*, *Microcorys exserta*, *Mirbelia spinosa*, *Persoonia teretifolia*, *P. tortifolia*, *Phebalium sp.*, *Pimelea sulphurea*, *Pityrodia axillaris*, *Olearia ciliata*, *Oxylobium ciliatum*, *Stylidium bulbiferum*, *S. zeicolor*, *Verticordia chrysantha*, *V. insignis*, *V. mitchelliana*, *V. picta*, *V. roei*, *Xanthorrhoea nana*.

As the plant lists are not complete, much of the difference between the northern and southern areas may be more apparent than real, and represent the vagaries of collecting. However, there are certainly some real differences, which in the present state of our knowledge appear to be the following:

Absence in the south of *Grevillea pterosperma*, *Acacia hynesiana*, *Acacia rossei*, *Banksia audax*, *Casuarina corniculata*, *Eucalyptus burracoppinensis*, *Eucalyptus leptopoda*, *Balaustion pulcherrimum*, *Verticordia pritzellii*.

Absence in the north of *Banksia laevigata*, *Banksia media*, *Isopogon sp. inedit. aff. teretifolius*, *Adenanthos flavida*, *Casuarina humilis*, *Chamelaucium megalopetalum*, *Leschenaultia spp.*, *Xanthorrhoea nana*.

2. Broom-bush Thicket

When of mature structure this formation is a closed community, and the characteristic species are those of its canopy layer. Under certain conditions an understory of scrub heath species may be present as previously described, and these need not be further listed. The broom-bush scrub is developed on two different substrata, ironstone gravels capping granitic uplands, and rocky knolls occurring in outcrops of basic rocks. The composition is slightly different in these two cases.

On granite the principal components are: *Acacia fragilis*, *A. resinomarginea*, *A. stereophylla*, *A. sp.* J.S.B.3400, *A. sp.* J.S.B.3415, *A. sp.* J.S.B.3774, *A. sp.* J.S.B.3775, *Casuarina acutivalvis*, *C. campestris*, *C. corniculata*, *C. dielsiana* or var., *C. helmsii*, *Eucalyptus foecunda*, *E. leptopoda*, *E. oleosa*, *Melaleuca acuminata*, *Thryptomene appressa*, *T. kochii*.

Not all of these species may be present at any one time, in fact it appears that three species of *Casuarina* and two of *Acacia* would be a normal association, but such local variations have not yet been studied.

Where this community presents a sharp boundary, as it sometimes does to granite outcrops or to sclerophyll woodland, one may find along the margin the small mallee *Eucalyptus grossa*.

On Mount Day in the Bremer Range, which is an outcrop of fine-grained basaltic rock forming a low dome of altitude approximately 1500 ft, the top and slopes (except partially in the steepest parts) are clothed with a broom-bush scrub. This was 4 ft tall in October, 1964, but dead, fire-killed relics of 8 ft were present. Composition was observed to be: *Casuarina campestris*, v.a.; *Calothamnus asper*, a.; *Eremophila sp.* 3841, o.; *Dodonaea ptermacifolia*, o.; *Acacia sp.* 3843, o.; *Melaleuca uncinata*, o.; *Cassia eremophila*, o.; *Scaevola oxycloa*, o.; *Eucalyptus oleosa*, forma, o. (mallee, up to 10 ft); *Triodia scariosa*, r.

On the steepest part of the east slope the scrub breaks into grass with scattered shrubs, the grasses including *Stipa juncifolia* and *Aristida arenaria* with herbs *Brunonia australis* and *Waitzia acuminata* and the subshrub *Ptilotus obovatus*. The major shrubs are the above *Dodonaea*, *Calothamnus*, *Acacia*, *Melaleuca* and *Cassia* with *Pittosporum phylliracoides*. At the foot of the steep slope the dense scrub is reformed, consisting almost entirely of *Casuarina*, *C. campestris*, *C. helmsii* and *C. sp. inedit.* J.S.B.3838.

Such scrub knolls with grassy openings are frequent in the Bremer Range, but composition was not examined elsewhere.

Scrub on basaltic hilltops in the Coolgardie system is rather taller and consists mainly of *Acacia sp.* 3377.

3. Rock Pavement Vegetation

The numerous granite outcrops throughout this region consist typically of low domes of almost bare rock exfoliating in thin sheets. The rock is not quite bare, but clad sparsely with lichens, while here and there are depressions and holes filled with water after rain which have a certain growth of algae and mosses, and patches of soil, perched upon the rock. The vegetation of these patches varies according to their size and depth. Where they are thin and small, the typical plant is *Borya nitida* growing in herbaceous tussocks. With more soil, certain shrubs characteristic of this habitat appear, notably *Kunzea sericea*, less typically *Calothamnus quadrifidus*, *Thryptomene australis*, *Melaleuca leiocarpa* and *Dodonaea attenuata*, with sedges, Restionaceae and herbs such as *Isotoma petraea*. Large patches of deep soil and boulders will tend to develop shrubs and

small trees of *Casuarina huegeliana* and *Acacia* spp. Around the outer edge of the outcrop the soil is at first shallow, though supplied with additional moisture by run-on. Shallow patches tend to resemble those on the rock itself, but the shrub *Melaleuca elliptica* is especially typical of this situation. Deep soil adjoining rocks carries dense groves of *Casuarina huegeliana* to 20 ft in height, or of an *Acacia* (unidentified Ac. 3352?). These usually merge into adjoining sclerophyll woodland with a belt containing *Eucalyptus loxophleba*.

Peak Charles differs rather markedly from other granite outcrops in size, height, steepness and other respects, and its vegetation has correspondingly unique features. The rock rises to 2160 feet above sea level, which implies about 1500 ft above the surrounding country, and consists of a pink granite. In many places the slopes are precipitous and bare of vegetation except lichens, but elsewhere patches of soil cling to the rock and scrub has developed. The summit is largely bare, with a few old, gnarled bushes of *Leptospermum* sp. inedit. (J.S.B.3821), 2 ft tall, growing in crevices. The middle slopes bear shrub thickets 4 to 6 ft tall, containing *Leptospermum* 3821, *Calothamnus quadrifidus* and *Calothamnus gilesii*, *Melaleuca fulgens*, *Callitris preissii*, subsp. *verrucosa*, *Baeckea behrii*, *Darwinia* sp., *Hibbertia mucronata*, *Labichea lanceolata*, *Anthocercis genistoides*, *Philotheca ericoides*, *Oxylobium parviflorum*.

On the lower slopes these also very largely occur with the addition of other species such as *Grevillea teretifolia*, *Santalum acuminatum* and *Santalum spicatum*, *Acacia* spp., *Casuarina humilis*. Besides this scrub, however, there are groves of *Casuarina huegeliana*, a tree up to 20 ft, or of mallee with *Eucalyptus loxophleba* and *Eucalyptus eremophila*. At the foot of the rock the tall scrub is joined by *Acacia acuminata* and *Pittosporum phylliracoides*.

Kunzea sericea was not observed on Peak Charles, its niche being occupied by *Melaleuca fulgens*, which is characteristic of granite outcrops in the Esperance area to the south-east. The range of *Kunzea sericea* is to the north-west as far as the Darling Range.

4. Mallee

The most consistent and abundant species in the mallee formation of this area is *Eucalyptus eremophila*, a variable species which occurs in a number of different forms and varieties. Associates are *Eucalyptus oleosa* vars., *Eucalyptus redunca*, *Eucalyptus incrassata*, *Eucalyptus pilcata*, *Eucalyptus leptophylla*, *Eucalyptus flocktoniae*, *Eucalyptus loxophleba*. Up to four species, of which *Eucalyptus eremophila* is normally one, tend to occur together in any one locality. Mallee which has resulted from burnt woodland may contain or consist of *Eucalyptus salubris* and *Eucalyptus gracilis*.

There are many variations in the ground layer beneath the mallee, from virtual absence to dense and continuous cover of low shrubs 2 to 4 ft tall. In the latter case *Melaleuca pungens* is the usual component. On sandy soil heath shrubs may be abundant, notably *Banksia media*, *Hakea laurina*, *Callitris preissii* subsp. *verrucosa*, *Melaleuca cordata*, *Leptospermum roei*, *Calytrix* aff. *decandra*, *Leschenaultia* sp. inedit., *Verticordia mitchelliana*. On heavy soil undergrowth is relatively sparse, but includes a number of typical shrub species, such as *Grevillea huegelii*, *Grevillea oncogyne*, *Eremophila calorhabdos*, *Eremophila dichroantha*, *Eremophila ?decepiens*, *Olearia adenolasia*, *Prostanthera arenicola*, and *Rulingia crauophylla*.

Mallee communities noted on the traverses were as follows:

Lake King-Norseman Road, at S.W. corner of Lake Johnston sheet—*Eucalyptus eremophila*, *Eucalyptus flocktoniae*, *Eucalyptus foecunda*, *Eucalyptus oleosa* var., *Eucalyptus* sp. unidentified (J.S.B.3740).

Ditto, vicinity of the 100-Mile Tank—*Eucalyptus eremophila*, *Eucalyptus flocktoniae*, *Eucalyptus pileata*, *Eucalyptus* sp. unidentified, with white fruits.

100-Mile Tank to Lake Hope—*Eucalyptus eremophila*, *Eucalyptus foecunda*. Young thickets of *Eucalyptus salubris* and *Eucalyptus gracilis* representing sclerophyll woodland in process of regeneration.

Norseman-Hyden Road, 315-300 Mile Peg—*Eucalyptus eremophila*, *Eucalyptus gracilis*, *Eucalyptus foecunda*, *Eucalyptus redunca*.

South of Woolgangie—*Eucalyptus eremophila*, *Eucalyptus loxophleba*, *Eucalyptus oleosa* var.

Woolgangie to Bullabulling—*Eucalyptus eremophila*, *Eucalyptus foecunda*, *Eucalyptus incrassata*.

No mallee has been observed in this area on greenstone.

5. Sclerophyll Woodland

In this formation there are a number of different association which may be readily recognized.

(a) *Eucalyptus transcontinentalis**-*Eucalyptus flocktoniae* association on the "granite eluvium" of the geological survey, i.e. red loam developed *in situ* on granite. Associated trees are *Eucalyptus gracilis* (o), *Eucalyptus corrugata* (f), *Eucalyptus salubris* (l.a.), *Eucalyptus melanoxylon* (l.f.). Undergrowth may be almost entirely lacking, but the few scattered shrubs seen include: *Alyxia buxifolia*, *Comesperma spinosum*, *Daviesia anthoclona*, *Dodonaea stenozyga*, *Eremophila dempsteri*, *Eremophila saligna*, *Eremophila* sp. inedit. J.S.B.3825, *Grevillea huegelii*, *Grevillea oncogyne*, *Melaleuca pauperiflora*, *Melaleuca pubescens*, *Melaleuca sheathiana*, *Santalum acuminatum*, *Scaccola spinescens*, *Westringia rigida*.

In places, mainly south of the Johnston Lakes, a low woodland may be encountered intermediate in structure between mallee and sclerophyll woodland proper, and composed of *Eucalyptus flocktoniae* and *Eucalyptus eremophila*, mostly with a dense understory of *Melaleuca pungens*.

(b) *Eucalyptus* aff. *striatocalyx*-*Eucalyptus leptophylla* association on sand ridges. These tend to occur to the south-east of salt lakes, in curved lines, conforming to the present lake margin. The ridges are low, well vegetated, and too limited in extent to be mapped. There are good examples between the 380 and 370 mile pegs on the Norseman-Hyden Road. The dominant species is a tree suggesting *Eucalyptus striatocalyx*, up to 40 ft tall, with persistent stringy bark on the lower trunk, together with a few salmon gum, *Eucalyptus salmonophloia*, and the sand salmon gum *Eucalyptus leptophylla*. The latter is only a small tree, but may form pure stands locally. Undergrowth consists of a fairly dense ground layer (2 ft) of spinifex *Triodia scariosa*, and the cyperaceous reed *Lepidosperma viscidum*.

(c) *Eucalyptus torquata*-*Eucalyptus le socufii* association on rocky greenstone ridges. This association occurs only in the Coolgardie system and is of limited extent in this area. *Eucalyptus torquata* and *Eucalyptus*

* For convenience, since these are important ecotypes readily recognizable in the field, it is preferred to use the forms *Eucalyptus transcontinentalis* Maiden and *Eucalyptus longicornis* F. Muell. rather than *Eucalyptus oleosa* F. Muell. var. *glauca* Maiden and var. *longicornis*. F. Muell.

le soeufii are co-dominant, abundant and characteristic. Associated trees are *Eucalyptus corrugata*, *Eucalyptus clelandii*, *Eucalyptus campaspe* and *Casuarina cristata*. There is an open shrub understory, largely of *Eremophila* spp. up to 6 ft tall and of "broom-bush" habit, notably *Eremophila scoparia*, *Eremophila glabra*, *Eremophila oldfieldii*, also *Dodonaea*, *Cassia* and *Acacia* species, interspersed with glaucous 4 ft shrubs of the "Old Man Saltbush", *Atriplex nummularia*. Forbs include *Ptilotus exaltatus*.

(d) *Eucalyptus le soeufii*-*Eucalyptus oleosa* association on deep soils developed on the greenstones and included granites. This also is confined to the Coolgardie system and is of limited extent within the Boorabbin map sheet. Composition is related both to that of the *Eucalyptus transcontinentalis*-*Eucalyptus flocktoniae* and *Eucalyptus torquata*-*Eucalyptus le soeufii* associations, all eucalypt components of both being present except for *Eucalyptus torquata* which is entirely absent, being confined to rocky ridges. A newcomer is *Eucalyptus oleosa* var. *obtusa*. Thus we have: *Eucalyptus le soeufii*, v.a.; *Eucalyptus oleosa* var. *obtusa*, l.a.; *Eucalyptus transcontinentalis* (*Eucalyptus oleosa* var. *glauca*), a.; *Eucalyptus clelandii*, f.; *Eucalyptus corrugata*, f.; *Eucalyptus campaspe*, l.f.; *Eucalyptus flocktoniae*, f.; *Eucalyptus gracilis*, o.

The understory does not differ significantly from that in the *Eucalyptus transcontinentalis*-*Eucalyptus flocktoniae* association.

(e) *Eucalyptus dundasii*-*Eucalyptus longicornis* association on deep soil over greenstone in the Bremer Range. The woodland shows a co-dominance of *Eucalyptus dundasii* and *Eucalyptus longicornis* (*Eucalyptus oleosa* var. *longicornis*), sometimes in mixture, sometimes in pure patches. The former of these is characteristic of greenstone soils further east, around and to the south of Norseman, and the latter of greenstone soils further west around Forrestania and in other localities. This woodland appears to be rather readily destroyed or damaged by fire and in many places there are young saplings and pole-sized stands consisting largely of *Eucalyptus corrugata* in addition to the above two species. Since *Eucalyptus corrugata* was nowhere observed in mature stands it may be that it is a relatively short-lived pioneer species: this merits further investigation. In the transition to *Casuarina* scrub on Mt Day there is a narrow band of *Eucalyptus celastroides* and *Eucalyptus* sp. (unidentified). Undershubs are extremely sparse, but the following were noted: *Eremophila* sp. inedit., J.S.B.3825; *Eremophila densifolia*; *Dodonaea stenozyga*; *Acacia* spp. On the low ground a saltbush *Cratystylis conocephala* is common.

(f) *Eucalyptus salmonophloia* consociation on alluvial soils, derived from both granite and greenstone. The composition of this association is very simple. Very commonly and most typically the tree layer consists of nothing but *Eucalyptus salmonophloia* and this seems to be associated with a light loam soil. Changes in soil tend to bring in some admixture, *Eucalyptus longicornis* on clay-loam, *Eucalyptus salubris* on stiff clay. *Eucalyptus melanoxylon* appears to indicate high base status, usually the presence of Kunkar. Under ecotonal conditions appropriate mixtures can be seen, e.g., with *Eucalyptus transcontinentalis*, *Eucalyptus flocktoniae* and their associates or with *Eucalyptus flocktoniae* and *Eucalyptus eremophila* (in marlock form) where the boundary is with mallee. In these cases, *Eucalyptus salmonophloia* being of superior stature, a layered woodland is formed. There is commonly a tall shrub layer of *Melaleuca* spp., e.g., *Melaleuca pauperiflora*, *Melaleuca pubescens*, and/or *Melaleuca sheathiana*. Shrubs are extremely sparse, but include many species of *Eremophila* and *Acacia*, *Daviesia*

nematophylla and *Daviesia anthoclona*. Where the soil is somewhat saline, there is a ground layer solely of saltbush, 18 inches high.

6. *Halophytes*. The vegetation of saline areas may be divided into two types, saltbush and samphire. The former may be found on alluvial soils in the vicinity of salt lakes, while the latter occurs in the lakes themselves, usually on raised beds forming a marked pattern in the lake. Not all lakes have these beds. The saltbush type begins as a ground layer under *Eucalyptus salmonophloia*, *Eucalyptus melanoxydon* or *Eucalyptus flocktoniae*, which become more and more scattered as salinity increases. On the east side of some lakes the trees may thin out completely to leave pure saltbush and grass as at Lake Hope, where the saltbushes *Atriplex paludosa* and *Frankenia interioris* and grasses *Danthonia setacea*, *Stipa elegantissima* were recorded. Occasionally at lake margins trees of *Eucalyptus kondininensis* are found, but this tree does not seem to be common in the area.

Samphires have not been studied and are assumed to be *Arthrocnemum* spp.

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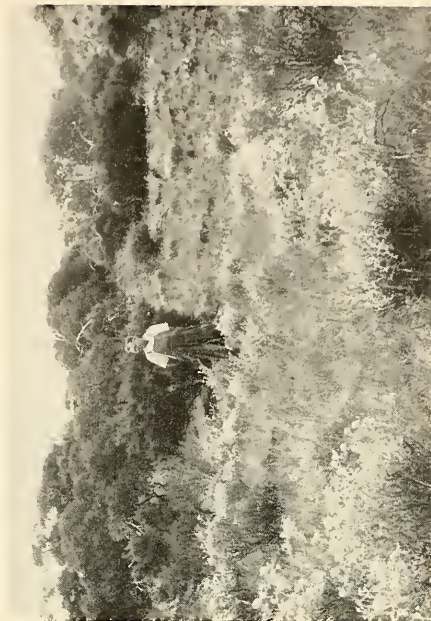
EXPLANATION OF PLATES

PLATE XVIII

- Top left. Sandheath east of Hyden, October, 1964. Stage of regeneration with abundant *Grevillea excelsior*, lower story of ericoid shrubs, *Verticordia roei* flowering.
 Top right. Sandheath east of Lake King near the rabbit-proof fence, October, 1964. Intermediate stage, well-developed Proteaceous shrubs (*Banksia elderana*, *Isopogon*) and *Casuarina* with low ericoid ground layer.
 Bottom left. Broombush thicket of *Casuarina* spp. Near Koorarawalyee, October, 1964.
 Bottom right. Grassy opening in thicket, Mount Day in the Bremer Range, October, 1964. Foreground: *Ptilotus obovatus* with *Stipa* and *Aristida*, behind shrubs of *Dodonaea*, *Calothamnus*, etc., and *Eucalyptus oleosa*.



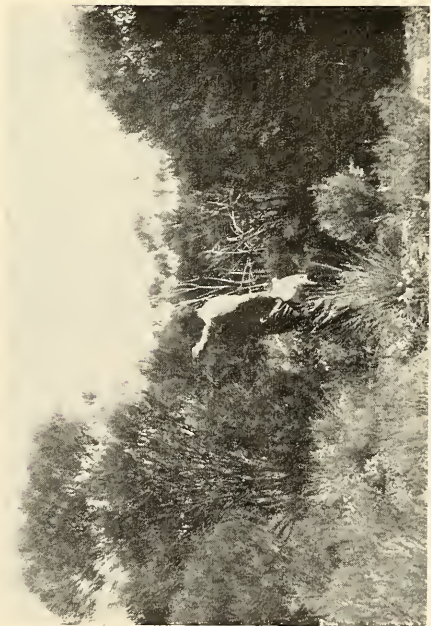
Scrub heath east of Lake King.



Grassy opening in thicket.



Scrub heath east of Hyden.



Broombush thicket of *Casuarina* spp.

The vegetation of the Boorabbin and Lake Johnston areas.